Predation is a biological interaction where one organism, the predator, kills and eats another organism, its prey.

Predation is a short-term interaction.

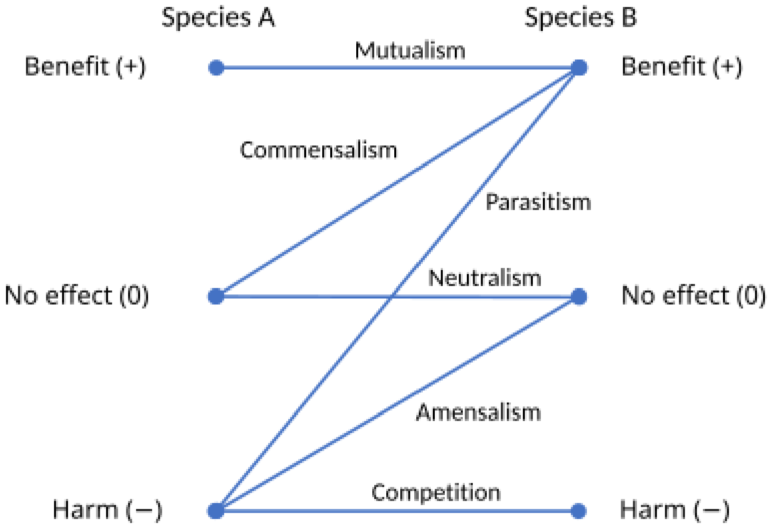
Short-term interactions, including predation and pollination, and seed dispersal, are extremely important in ecology and evolution.

Since plants have limited mobility, they rely upon a variety of dispersal vectors to transport their propagules, including abiotic vectors such as wind and biotic vectors like birds.

Dandelion is a wind-dispersed species.

Long-term interactions

The six possible types are mutualism, commensalism, parasitism, neutralism, amensalism, and competition. Distinguished and classified by the effect on fitness of each participant, from mutual benefit to mutual harm.



Consumer–resource interactions

Consumer–resource interactions are the core motif of ecological food chains or food webs, and are an umbrella term for a variety of more specialised types of biological species interactions including prey-predator, host-parasite, plant-herbivore and victim-exploiter systems.

Role in ecosystems

Predators affect their ecosystems not only directly by eating their own prey, but by indirect means such as reducing predation by other species, or altering the foraging behaviour of a herbivore —as with the biodiversity effect of wolves on riverside vegetation.
The 'biodiversity effect' refers to a cascading ecological impact in ecosystems, like Yellowstone National Park where the reintroduction of wolves led to a reduction in the population of elk, its primary prey. The elk had previously overgrazed riverside vegetation, such as willows and aspens, due to the absence of predation. When wolves were reintroduced, the fear made them cautious, reducing the time they spent grazing near rivers. This allowed the vegetation to recover, which, in turn, benefited other species—like beavers and birds—by restoring habitats and increasing biodiversity. This chain of ecological interactions, initiated by the presence of a top predator like the wolf is an example of a trophic cascade.

Trophic cascade

Trophic cascades are powerful indirect interactions that can control entire ecosystems. Trophic cascades occur when predators limit the density and/or behaviour of their prey and thereby enhance survival of the next lower trophic level.

Trophic, from Greek *trophikos*, from *trophē* ‘nourishment,’ (originally denoting nerves believed to control the nutrition of organs and tissues).

The trophic level of an organism is the number of steps it is from the start of the food chain. A food web starts at trophic level 1 with primary producers such as plants, can move to herbivores at level 2.

Search

Predators have a choice of search modes ranging from *sit-and-wait* to *active* or *widely foraging*.

Foraging is searching for wild food resources.

Anti-predator adaptations

Are mechanisms developed through evolution that assist prey in their constant struggle against predator. Throughout the animal kingdom, adaptations have evolved for every stage of this struggle.

Deception in animals

Deception in animals is the transmission of misinformation by one animal to another, of the same or different species, in a way that propagates beliefs that are not true.
Prey animals may appear as predators, or vice versa; both predators and prey may be hard to see (crypsis), or may be mistaken for other objects (mimesis). In Batesian mimicry, harmless animals may appear to be distasteful or poisonous. In automimicry, animals may have eyespots in less important parts of the body than the head, helping to distract attack and increase the chance of survival. In more active forms of anti-predator adaptation, animals may feign death when they detect a predator, or may quickly conceal themselves. In deimatic behaviour, a harmless animal adopts a threatening pose or displays startling. Some animals may use tactical deception, with behaviour that is deployed in a way that other animals misinterpret what is happening to the advantage of the agent.

Overview

Some types of deception in animals are completely involuntary (e.g. disruptive coloration), but others are under voluntary control and may involve an element of learning.

Most instances of voluntary deception in animals involve a simple behaviour, such as a cat arching its back and raising its hackles, to make itself appear larger than normal when attacked.

There are relatively few examples of animal behaviour which might be attributed to the manipulative type of deception which we know occurs in humans, i.e. "tactical deception".

It has been argued that true deception assumes the deceiver knows that (1) other animals have minds, (2) different animals' minds can believe different things are true (when only one of these is actually true), and (3) it can make another mind believe that something false is actually true.

True deception requires the deceiver to have the mental capacity to assess different representations of reality.

In evolutionary biology, an evolutionary arms race is an ongoing struggle between competing sets of co-evolving genes, phenotypic and behavioral traits that develop escalating adaptations and counter-adaptations against each other.

When a species has not been subject to an arms race previously, it may be at a severe disadvantage and face extinction well before it could ever hope to adapt to a new predator, competitor, etc. This should not seem surprising, as one species may have been in evolutionary struggles for millions of years while the other might never have faced such pressures. This is a common problem in isolated ecosystems such as Australia or the Hawaiian Islands. Introduced species are a major reason why some indigenous species become endangered or even extinct.

The first line of defence consists in avoiding detection, alternatively, prey animals may ward off attack, whether by advertising the presence of strong defences in aposematism, by mimicking animals which do possess such defences, by startling the attacker, by signalling to the predator that pursuit is not worthwhile, by distraction, by using defensive structures such as spines, and by living in a group. Members of groups are at reduced risk of predation, despite the increased conspicuousness of a group, through improved vigilance, predator confusion, and the likelihood that the predator will attack some other individual.

Adaptations of prey that allow them to avoid predators are widespread, those that make them hard to find being collectively known as crypsis.

Crypsis

In ecology, crypsis is the ability of an animal or a plant to avoid observation or detection by other animals. It may be a predation strategy or an anti-predator adaptation.

Crypsis may involve temporal evasion such as nocturnality, behavioural methods such as hiding, non-behavioral adaptations such as camouflage, subterranean lifestyle and mimicry.

Crypsis can be visual, olfactory (with pheromones) or auditory concealment.

Overview

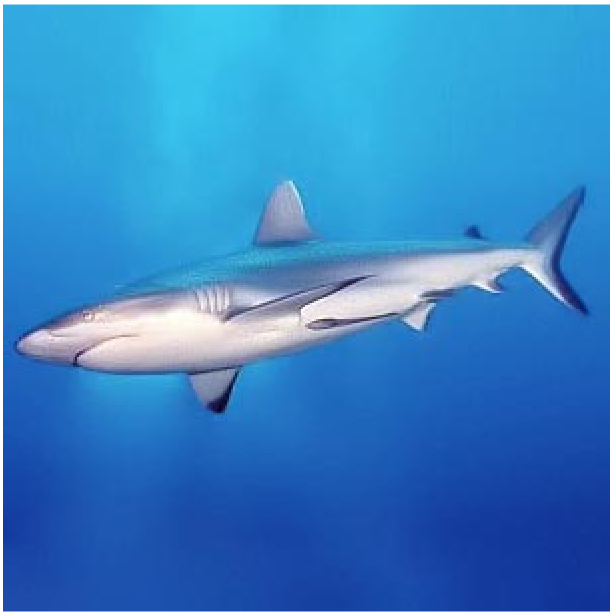
There is a strong evolutionary pressure for animals to blend into their environment or conceal their shape. Exceptions include large herbivores without natural enemies, brilliantly coloured birds that rely on flight to escape predators, and venomous or otherwise powerfully armed animals with warning coloration.

Nocturnality is a behaviour in some non-human animals characterised by being active during the night and sleeping during the day.

Concealment

Many animals hide from predators behind rocks, in holes, in brush, and in many other ways.
Some actually carry around parts of the environment to use for that purpose. For example, at least four individual veined octopuses were seen retrieving discarded coconut shells, carrying them up to 20 metres, manipulating them, and then assembling them to use as shelter.

Countershading



Self-shadow concealment that flattens the form.

Countershading, or Thayer's law, is a method of camouflage in which an animal's coloration is darker on the top or upper side and lighter on the underside of the body.

Thayer's original argument, restated by Cott, was that nature did the exact opposite with countershading that an artist did with paint when creating the illusion of solid three-dimensionality.

Countershading is observed in a wide range of animal groups, both terrestrial, such as deer, and marine, such as sharks.

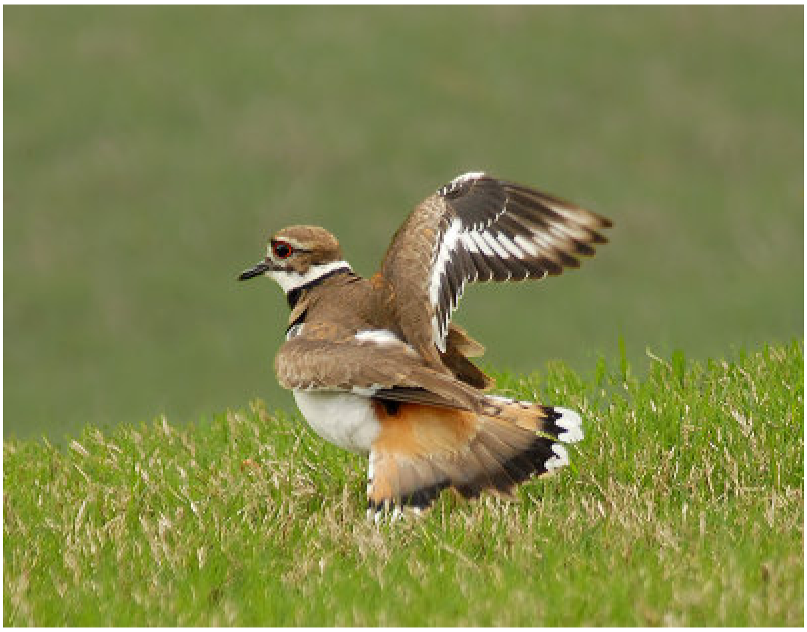
It is the basis of camouflage in both predators and prey.

Distraction displays

Distraction displays, also known as diversionary displays, or paratrepsis are anti-predator behaviours used to attract the attention of an enemy away from something, typically the nest or young, that is being protected by a parent. Distraction displays are sometimes classified more generically under "nest protection behaviours" along with aggressive displays such as mobbing.

Distraction displays frequently take the form of injury-feigning. These displays have been studied most extensively in bird species—but also have been documented in populations of stickleback fish and in some mammal species—broken-wing displays are most easily provoked and most realistic in shorebirds, waterfowl, and other species with ground nests. Animals may also mimic foraging behaviours away from the nest or simply draw attention to oneself. They may also imitate alternative prey item for the predator; some displays give the impression of a running small mammal. For instance, in the "rodent-run" display of the tundra-nesting Purple Sandpiper, the bird drags its wings (creating the illusion of a second pair of legs), erects its feathers (providing some resemblance to fur), and "squeals" while it dodges between imaginary barriers.

There is little doubt that effectively leading a predator away from the nest would be strongly favoured by natural selection, but how these stylized antics evolved remains controversial among behaviourists. Some conclude that distraction displays are a product of the conflicting desires of the parent to approach the predator aggressively, to return to the nest, and to retreat. Others suggest that they evolved directly as a predator defence, with more stylized sequences found in species that have had longer association with heavy predation. In either case, fear is a prerequisite; tame birds cannot be induced to perform distraction displays. Similarly, distraction displays may be reduced or eliminated from the behavioural repertoire through habituation to repeated non-damaging intrusions by predators (or experimenters).



Killdeer feigning a broken wing

Ideas about conflicting impulses suggest that the incorporation of sexual and threat displays into the distraction display may represent displacement. Displacement occurs when an animal, unable to satisfy two conflicting impulses, may initiate an out-of-context behaviour to vent.

Displacement activity

Occur when an animal experiences high motivation for two or more conflicting behaviours: the resulting displacement activity is usually unrelated to the competing motivations.

Head-scratching, an example of a displacement activity in humans.

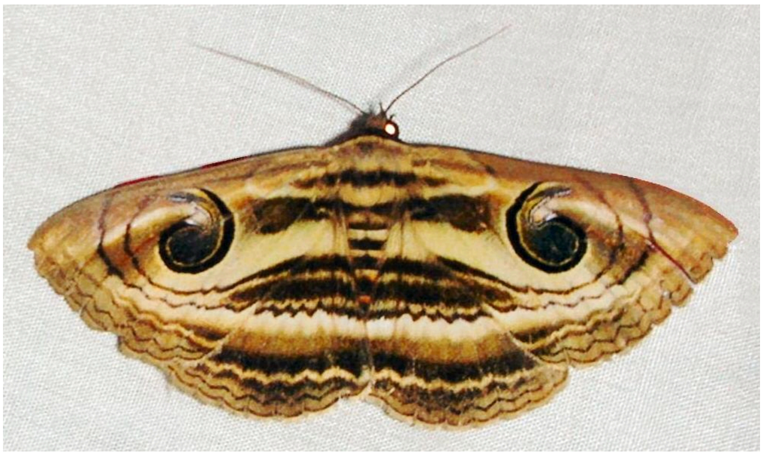
In 1940, two Dutch researchers Kortlandt and Tinbergen independently identified what was to become known as displacement activities. The subsequent development of research on displacement activities arose from Konrad Lorenz's works on instincts.

Tinbergen in 1952 noted, for example, that "two skylarks engaged in furious combat [may] suddenly peck at the ground as if they were feeding", or birds on the point of mating may suddenly begin to preen themselves. Tinbergen adopted the term "displacement activities" because the behaviour appeared to be displaced from one behavioural system into another.

In 1902, in *The Little White Bird*, J. M. Barrie refers to sheep in Kensington Gardens nibbling the grass in nervous agitation immediately after being shorn, and to Solomon, the wise crow, drinking water when he was frustrated and outwitted in an argument with other birds. Another bird encourages him to drink in order to compose himself. These references to displacement activities in a work of literature indicate that the phenomenon was well recognized at the turn of the twentieth century.

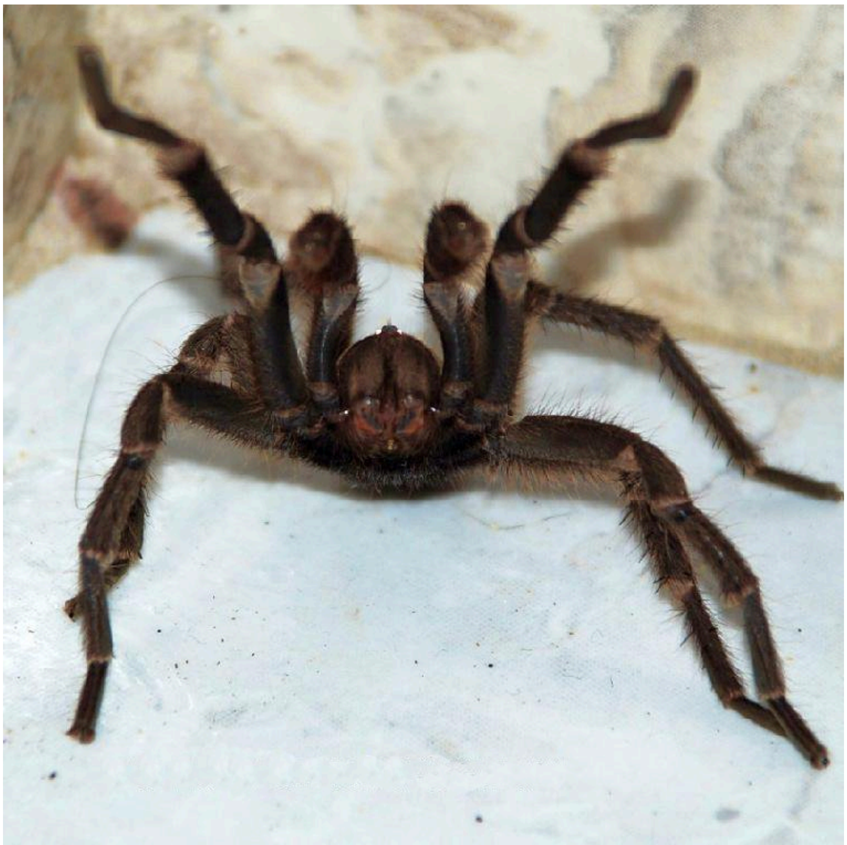
Deimatic behaviour

Deimatic behaviour or startle display means any pattern of bluffing in an animal that lacks strong defences. The term originates from the Greek δειματόω (deimatóo), meaning "to frighten".



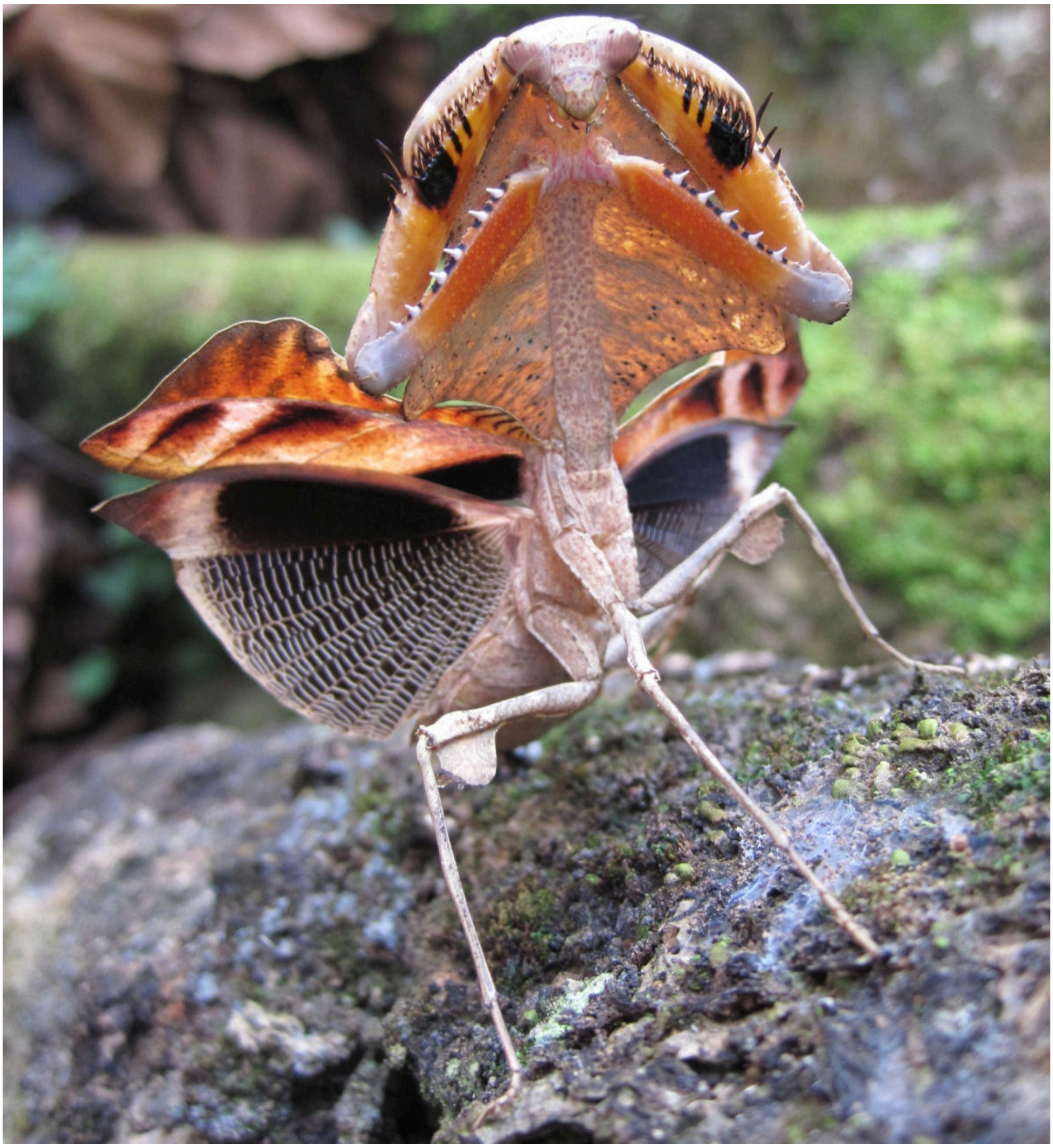
Spirama helicina resembling the face of a snake in a deimatic display

Displays are classified as deimatic or aposematic by the responses of the animals that see them. Where predators are initially startled but learn to eat the displaying prey, the display is classed as deimatic. However, these categories are not necessarily mutually exclusive. It is possible for a behaviour to be both deimatic and aposematic, if it both startles a predator and indicates the presence of anti-predator adaptations.



Aposematic threat display of Brazilian tarantula

Many weakly-defended animals make use of patterns of threatening or startling behaviour. In the absence of toxins or other defences, this is essentially bluffing, in contrast to aposematism which involves honest signals.



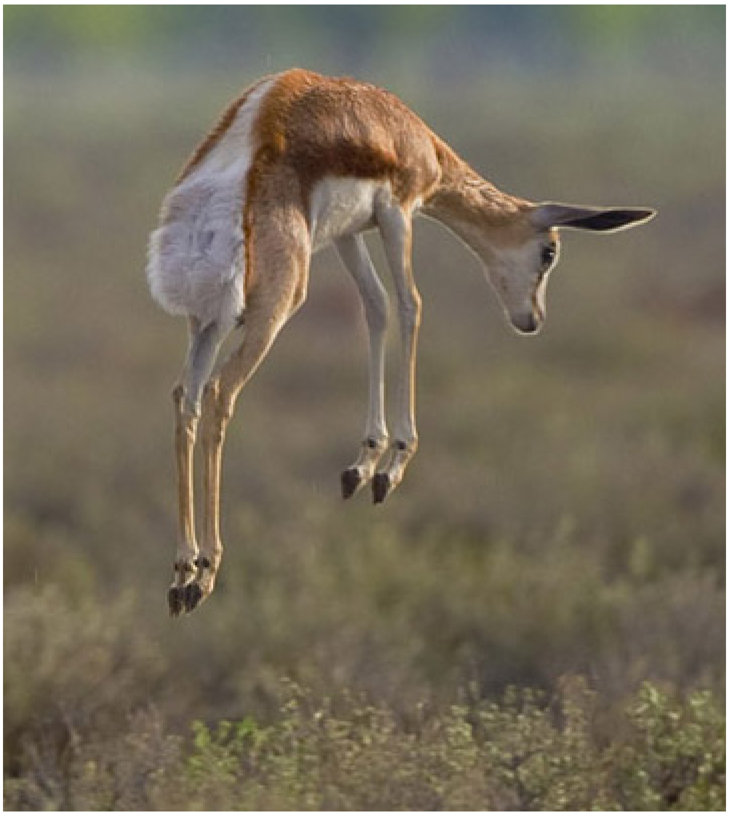
Deroplatys desiccata

Signalling theory

In biology, signals are traits, including structures and behaviours, that have evolved specifically because they change the behaviour of receivers in ways that benefit the signaller. Traits or actions that benefit the receiver and increase the risk of predation, is not a signal, but a cue.
Signalling systems are shaped by mutual interests between signallers and receivers.

Pursuit-deterrent signals

Pursuit-deterrent signals are behaviours displayed by prey to discourage predators from giving chase. For instance, gazelles stot, jumping high with stiff legs and an arched back. This is thought to show predators that the gazelles are highly fit; as a result, predators may choose to pursue a different prey that is less likely to outrun them. White-tailed deer flag with conspicuous (often black and white) tail markings when alarmed, informing the predator that it has been detected. Warning calls given by birds such as the Eurasian jay are similarly honest signals, benefiting both predator and prey: the predator is informed that it has been detected and might as well save time and energy by giving up the chase, while the prey is protected from attack.



By stotting (also called pronking), a springbok (Antidorcas marsupialis) signals honestly that the chase will be unprofitable.

Playing dead

Another pursuit-deterrent signal is thanatosis (or playing dead). Thanatosis is a form of bluff in which an animal mimics its own dead body. Thanatosis hinges on the pursuer's becoming unresponsive to its victim, as most predators only catch live prey, the predator loses interest in the "dead" prey.

Virginia opossum playing dead or *playing possum*—an idiom

Signals may be honest, conveying information which usefully increases the fitness of the receiver, or dishonest.

An individual can cheat by giving a dishonest signal, which might briefly benefit that signaller, at the risk of undermining the signalling system for the whole population.

An example of dishonest signalling comes from Fiddler crabs. Male Austruca mjoebergi rely heavily on their enlarged claws to signal dominance and fighting prowess. Crabs which lose their large claws will occasionally regrow a lighter, cheaper claw (requiring less energy to produce) that nevertheless intimidates crabs with smaller but stronger claws. The proportion of dishonest signals is low enough for it not to be worthwhile for crabs to test the honesty of every signal through combat.

Tactical deception

Withholding information, a form of tactical deception, can be costly to the deceiver. For example, rhesus monkeys discovering food announce their discoveries by calling on 45% of occasions. Discoverers who fail to call, but are detected with food by other group members, receive significantly more aggression than vocal discoverers. Presumably because of such costs to deceivers, tactical deception occurs rather rarely. It is thought to be more common in forms and species where the cost of ignoring the possibly deceptive act is even higher than the cost of believing. For example, tufted capuchin monkeys sometimes emit false alarm calls. The cost of ignoring one of these calls could be death, which may lead to a ‘better safe than sorry’ approach, even when the caller is a known deceiver.

Cheating

Cheating is a term used in behavioural ecology and ethology to describe behaviour whereby organisms receive a benefit at the cost of other organisms. Cheating is common in many mutualistic and altruistic relationships.

Organisms communicate and cooperate to perform a wide range of behaviours.

Mutualism, or mutually beneficial interactions between species, is common in ecological systems. These interactions can be thought of as "biological markets" in which species offer partners goods that are relatively inexpensive for them to produce and receive goods that are more expensive or even impossible for them to produce. However, these systems provide opportunities for exploitation by individuals that can obtain resources while providing nothing in return. Cheaters are also those who selfishly use common resources to maximise their individual fitness at the expense of a group.

Natural selection favours cheating, but there are mechanisms to regulate it.

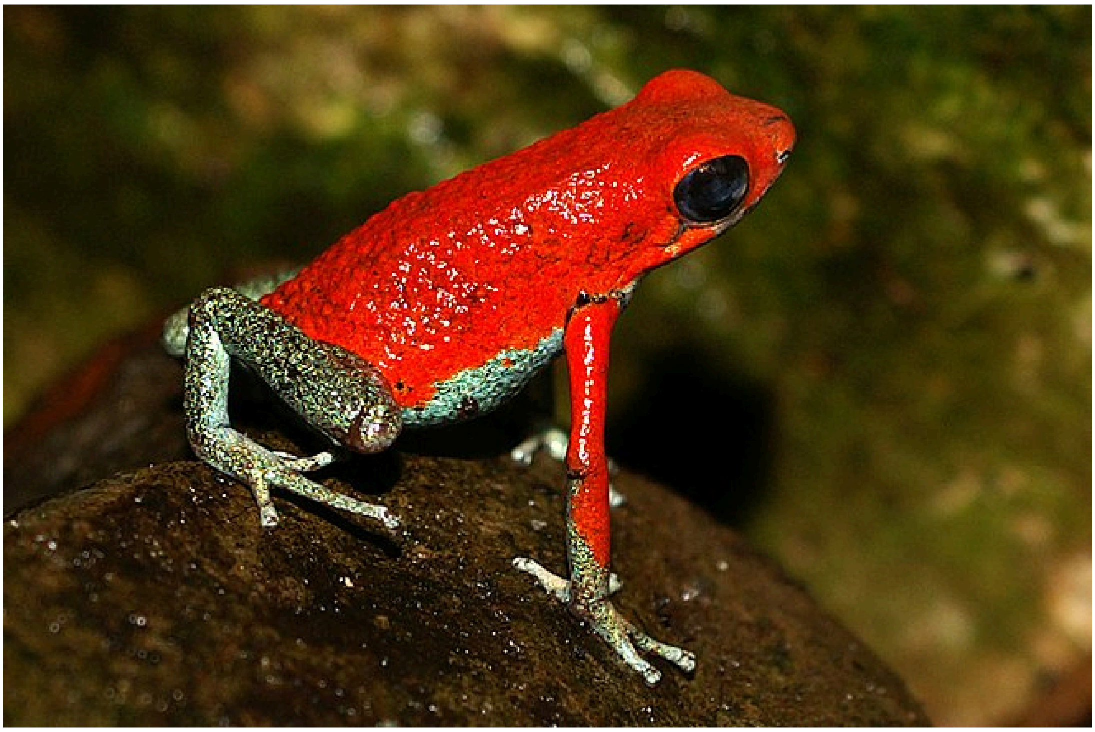
If individuals who cheat are able to gain survivorship and reproductive benefits while incurring no costs, natural selection should favour ‘em. However, mechanisms also exist that prevent cheaters from undermining mutualistic systems. One main factor is that the advantages of cheating are often frequency-dependent.

Frequency-dependent selection occurs when the fitness of a phenotype depends on its frequency relative to other phenotypes in a population. Cheater phenotypes exhibit negative frequency-dependent selection, a scenario where the fitness of a phenotype increases as it becomes less common in the population. This dynamic helps maintain a balance. In other words, cheaters do best when there are relatively few of them, but as cheaters become more abundant, they do worse.

Studies of cheating and dishonest communication in populations presupposes an organismal system that cooperates.

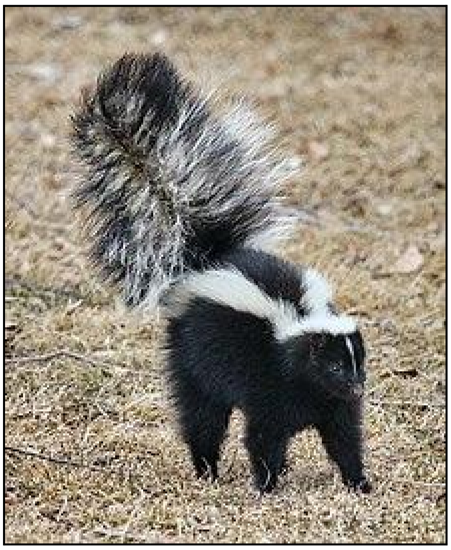
Aposematism

Aposematism is the advertising by an animal, whether terrestrial or marine, to potential predators that it is not worth attacking or eating. This unprofitability may consist of any defences which make the prey difficult to kill and eat, such as toxicity, venom, foul taste or smell, sharp spines, or aggressive nature. These advertising signals may take the form of conspicuous coloration, sounds, odours, or other perceivable characteristics. Aposematic signals are beneficial for both predator and prey, since both avoid potential harm.



The bright colours of the granular poison frog.

The term, from the Ancient Greek words ἀπό (apo, 'away') and σῆμα (sēma, 'sign'), was coined in 1877 by Edward Bagnall Poulton for Alfred Russel Wallace's concept of warning coloration.



Skunk, Mephitis mephitis, advertising its powerful defences, scent glands near the tail, by raising its tail and displaying its warning coloration.

Warning signals are honest indications ‘cause conspicuousness evolves in tandem with noxiousness. This contrasts with deimatic displays. Besides, aposematic species do not need to hide or stay still as cryptic organisms do, so aposematic individuals benefit from more freedom in exposed areas and can spend more time foraging.

The honey badger's reverse countershading makes it conspicuous, honestly signalling its ability to defend itself through its aggressive temperament.

Aposematism is a sufficiently successful strategy to have had significant effects on the evolution of both aposematic and non-aposematic species. Non-aposematic species often evolve to mimic.
Aposematism is paradoxical in evolutionary terms, as it makes individuals conspicuous to predators, so they may be killed and the trait eliminated before predators learn to avoid it.

Behaviour

The mechanism of defence relies on the memory of the would-be predator.

Dietary conservatism

Dietary conservatism is a foraging strategy in which individuals show a prolonged reluctance to eat novel foods, even after neophobia has been overcome. Within any given population of foragers, some will be conservative and some will be adventurous. Dietary conservatism and neophobia are however distinct processes. It has long been recognised that animals hesitate to approach novel foods they encounter and this initial fear of novelty (the literal meaning of "neophobia") lasts only a matter of minutes in most animals. By contrast, a second response to novel food has been identified, in which, after the foragers have overcome their neophobia to approach and made contact with novel food, they continue to avoid eating it for considerable periods of time. This much longer avoidance of novel food is called dietary conservatism, and has a genetic basis. Unlike neophobia, DC does not rapidly subside over repeated encounters. For example, Kelly (2001) found that among wild birds, some individuals avoided novel food for more than 2 years and 200 exposures, even though the novel food was conspicuous and fully palatable.

Mimicry

In evolutionary biology, mimicry is an evolved resemblance between an organism and another object, often an organism of another species. Mimicry may evolve between different species, or between individuals of the same species. Mimicry evolves if a receiver (such as a predator) perceives the similarity between a mimic (the organism that has a resemblance) and a model (the organism it resembles) and as a result changes its behaviour in a way that provides a selective advantage to the mimic. The resemblances that evolve in mimicry can be visual, acoustic, chemical, tactile, or electric, or combinations of these sensory modalities. Mimicry may be to the advantage of both organisms that share a resemblance, in which case it is a form of mutualism; or mimicry can be to the detriment of one, making it parasitic or competitive. The evolutionary convergence between groups is driven by the selective action of a signal-receiver or dupe. Birds, for example, use sight to identify palatable insects and butterflies, whilst avoiding the noxious ones. Over time, palatable insects may evolve to resemble noxious ones, making them mimics and the noxious ones models. In the case of mutualism, sometimes both groups are referred to as "co-mimics". Many harmless species, such as hoverflies, are Batesian mimics of strongly defended species, such as wasps. Meanwhile, well-defended species form Müllerian mimicry rings, all resembling each other. Mimicry between prey species and their predators often involves three or more species.

In its broadest definition, mimicry can include non-living models. The specific terms masquerade and mimesis are sometimes used when the models are inanimate. Animals—for instance, flower mantises, planthoppers, comma and geometer moth caterpillars—resemble twigs, bark, leaves, bird droppings, or flowers. Bird dropping mimicry is an interesting example. Certain moths and caterpillars look like bird droppings to avoid predators. Predators often ignore these insects because they mistake them for faeces, which are not appetising.

Many creatures bear eyespots, which are hypothesised to resemble the eyes of larger animals. They may not resemble any specific organism's eyes, and whether or not animals respond to them as eyes is also unclear. Nonetheless, eyespots are the subject of a rich contemporary literature. The model is usually another species, except in automimicry, where members of the species mimic other parts of their own bodies, and in inter-sexual mimicry, where members of one sex mimic members of the other.

Mimicry can result in an evolutionary arms race if mimicry negatively affects the model, and the model can evolve a different appearance from the mimic.

Mimicry should not be confused with other forms of convergent evolution that occur when species come to resemble each other by adapting to similar lifestyles that have nothing to do with a common signal receiver.

Mimics may have different models for different life cycle stages.
Models themselves may have more than one mimic; yet, frequency-dependent selection favours mimicry where models outnumber mimics. Models tend to be relatively closely related organisms, but mimicry of vastly different species is also known.

Most mimics are insects, although examples involving vertebrates are also known. The primary difference between mimicry in vertebrates and insects is the decreased diversity and frequency observed in vertebrates. The 50,000 extant vertebrates are dwarfed by the over 1 million known invertebrates. Plants and fungi may also be mimics, though less research has been carried out in this area.

Defensive

Defensive or protective mimicry takes place when organisms are able to avoid harmful encounters by deceiving enemies into treating them as something else.

Batesian mimicry

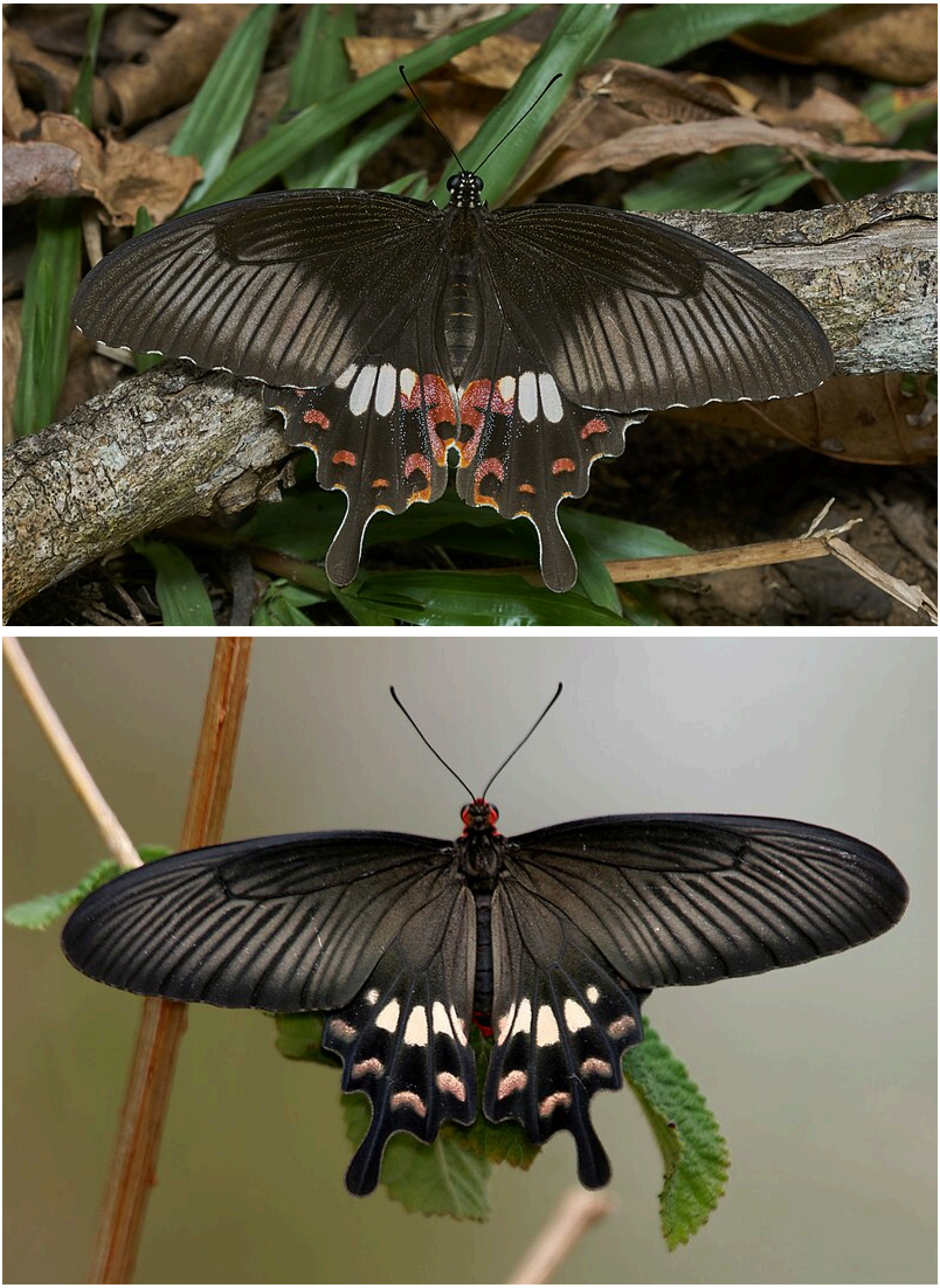
A form of mimicry where a harmless species has evolved to imitate the warning signals of a harmful species directed at a predator of them both. It is named after the English naturalist Henry Walter Bates, who worked on butterflies in the rainforests of Brazil.
zse43Batesian mimicry is the most commonly known and widely studied of mimicry complexes, such that the word mimicry is often treated as synonymous with Batesian mimicry.

The success of this dishonest display depends on the level of toxicity of the model and the abundance of the model in the geographical area.Batesian mimicry at higher frequency provides a stronger selective advantage for the predator to distinguish mimic from model. For this reason, mimics are usually less numerous than models. Some mimetic populations have evolved multiple forms (polymorphism), enabling them to mimic several different models and thereby to gain greater protection.

While visual signals have attracted most study, Batesian mimicry can employ deception of any of the senses; some moths mimic the ultrasound warning signals sent by unpalatable moths to bat predators, constituting auditory Batesian mimicry, while some weakly electric fish appear to mimic the electrolocation signals of strongly electric fish, probably constituting electrical mimicry.

Historical background

Bates's field research included collecting almost a hundred species of butterflies from the families Ithomiinae and Heliconiinae, as well as thousands of other insect specimens. In sorting these butterflies into similar groups based on appearance, inconsistencies began to arise. Some appeared superficially similar to others, so much so that even Bates could not tell some species apart based only on wing appearance. However, closer examination of less obvious morphological characters seemed to show that they were not even closely related. Shortly after his return to England, he read a paper on his theory of mimicry at a meeting of the Linnean Society of London on 21 November 1861, which was then published in 1862 as 'Contributions to an Insect Fauna of the Amazon Valley' in the society's Transactions. He elaborated on his experiences further in The Naturalist on the River Amazons. He noted that some species showed very striking coloration and flew in a leisurely manner, almost as if taunting predators to eat them. He reasoned that these butterflies were unpalatable to birds and other insectivores, and were thus avoided by them. He extended that logic to forms that closely resembled such protected species and mimicked their warning coloration but not their toxicity.

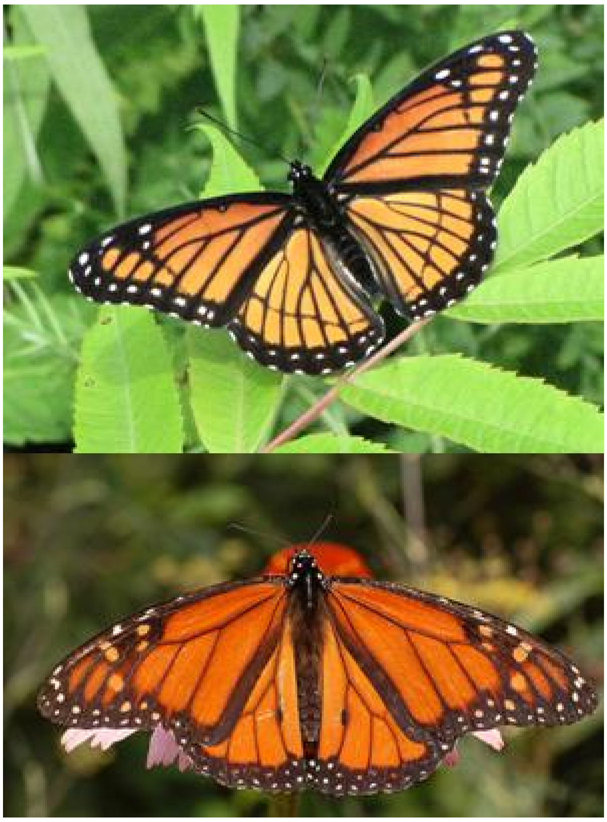


A well-known mimic, Papilio polytes (top) resembles the unpalatable Pachliopta aristolochiae (bottom).

Müllerian mimicry

Müllerian mimicry is a natural phenomenon in which two or more well-defended species sharing common predators have come to mimic each other's honest warning signals, to their mutual benefit.

The benefit to Müllerian mimics is that predators only need one unpleasant encounter with one member of a set of Müllerian mimics, and thereafter avoid all similar coloration, whether or not it belongs to the same species as the initial encounter.



The viceroy butterfly (top) appears very similar to the noxious-tasting monarch butterfly (bottom). Although it was for a long time purported to be an example of Batesian mimicry, the viceroy has recently been discovered to be just as unpalatable as the monarch, making this a case of Müllerian mimicry.

Müller wrote in 1878 that "defended species may evolve a similar appearance so as to share the costs of predator education."

Many different prey of the same predator could all employ their own warning signals, but this would make no sense for any party. If they could all agree on a common warning signal, the predator would have fewer detrimental experiences, and the prey would lose fewer individuals educating it. This can lead to the evolution of both Batesian and Müllerian mimicry, depending on whether the mimic is itself unprofitable to its predators, or just a free-rider.

In marketing

The evolutionary zoologist Thomas N. Sherratt suggests that different types of mimicry occur in brand and product marketing. He notes that distinctive forms like the Coca-Cola bottle's shape are defended by businesses, whereas rival companies have often imitated such famous motifs to benefit from the investment and reputation of their well-known competitors, constituting Batesian mimicry. Sherratt observes that the packaging of British supermarket own brands of potato crisps are consistently colour-coded red for the ready-salted variety, green for salt and vinegar, and blue for cheese and onion. He argues that this sharing of pattern is very unlikely to have arisen by chance, in which case the resemblance is intentionally to inform customers reliably (honest signalling) of what each package contains, to mutual benefit in the manner of Müllerian mimicry.

Gilbertian mimicry

Gilbertian mimicry involves only two species. The potential host (or prey) drives away its parasite (or predator) by mimicking it, the reverse of host-parasite aggressive mimicry. It was coined by Pasteur as a phrase for such rare mimicry systems, and is named after the American ecologist Lawrence E. Gilbert.

Gilbertian mimicry occurs in the genus Passiflora. The leaves of this plant contain toxins that deter herbivorous animals. However, some Heliconius butterfly larvae have evolved enzymes that break down these toxins, allowing them to specialise on this genus. This has created further selection pressure on the host plants, which have evolved stipules that mimic mature Heliconius eggs near the point of hatching. These butterflies tend to avoid laying eggs near existing ones, which helps avoid exploitative intraspecific competition between caterpillars — those that lay on vacant leaves provide their offspring with a greater chance of survival. Most Heliconius larvae are cannibalistic, meaning that on leaves older eggs hatch first and eat the new arrivals. Thus, it seems that such plants have evolved egg dummies under selection pressure from these grazing herbivore enemies. In addition, the decoy eggs are also nectaries, attracting predators of the caterpillars such as ants and wasps as a further defence.

Vavilovian mimicry

In plant biology, Vavilovian mimicry (also crop mimicry or weed mimicry) is a form of mimicry in plants where a weed evolves to share one or more characteristics with a domesticated plant through generations of artificial selection. It is a form of disjunct mimicry with the model agreeable to the dupe. In disjunct mimicry complexes, three different species are involved as model, mimic and dupe—the weed, mimicking a protected crop model, with humans as signal receivers (dupe).

Emsleyan mimicry, also called Mertensian mimicry, describes an unusual type of mimicry where a deadly prey mimics a less dangerous species.

The scenario for Emsleyan mimicry is a little more difficult to understand than for other types of mimicry, since in other types of mimicry it is usually the most harmful species that is the model. But if a predator dies, it cannot learn to recognize a warning signal. In other words, there is no advantage in being aposematic for an organism that is likely to kill any predator it succeeds in poisoning; such an animal is better off being camouflaged, to avoid attacks altogether. Still, if there were some other species that were harmful but not deadly as well as aposematic, the predator could learn to recognize its particular warning colours and avoid such animals. A deadly species could then profit by mimicking the less dangerous aposematic organism if this reduces the number of attacks.

‘

Aggressive

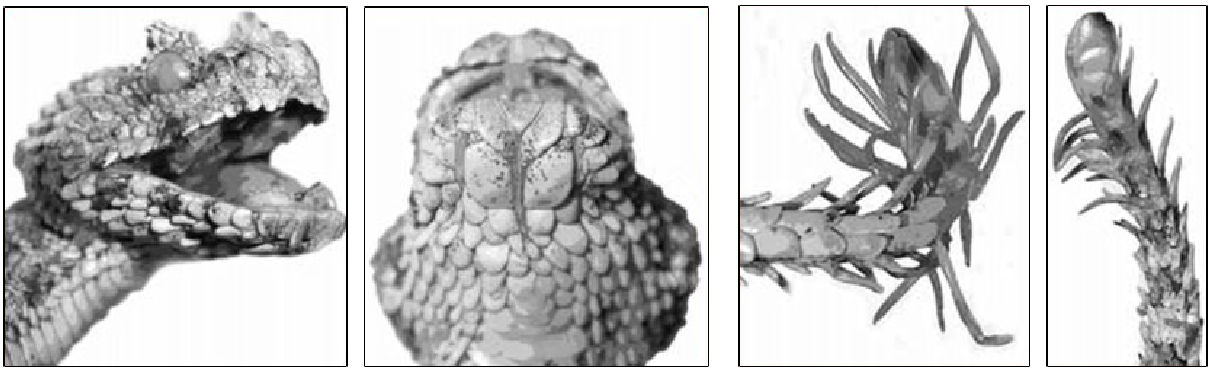
Aggressive mimicry is a form of mimicry in which predators, parasites, or parasitoids share similar signals, using a harmless model, allowing them to avoid being correctly identified by their prey or host.

Aggressive mimicry could include various types of exploitation, as when an orchid exploits a male insect by mimicking a sexually receptive female (see pseudocopulation).

Treated separately is molecular mimicry, for instance a virus may mimic the molecular properties of its host, allowing it access to its cells.

Aggressive mimicry often involves the predator employing signals which draw its potential prey towards it, a strategy which allows predators to simply sit and wait for prey to come. The promise of food or sex are most commonly used as lures.

In *caudal luring*, the predator uses tail movements to attract prey. This form of mimicry is used by several species, namely the Spider-tailed horned viper, whose tail looks like a spider thus attracting birds.



Pseudocerastes urarachnoides

On a different note, The Horned Lizard (Phrynosoma spp.) uses its tail to mimic the appearance of its body, aiding in defence rather than predation (see automimicry).

Other caudal luring-like movements occur as warning signals and are induced by stressful circumstances.

Back to aggressive mimicry, males are lured toward what seems to be a sexually receptive female, only to be eaten.

Fireflies of the genus Photuris emit the same light signals that females of the genus Photinus emit as a mating signal. Male fireflies from several different genera are attracted to these "femmes fatales" because the predatory females can identify the male's species and emit the signal used by the female of the male's species. This mimicry may have evolved from non-mating signals that have become modified for predation.

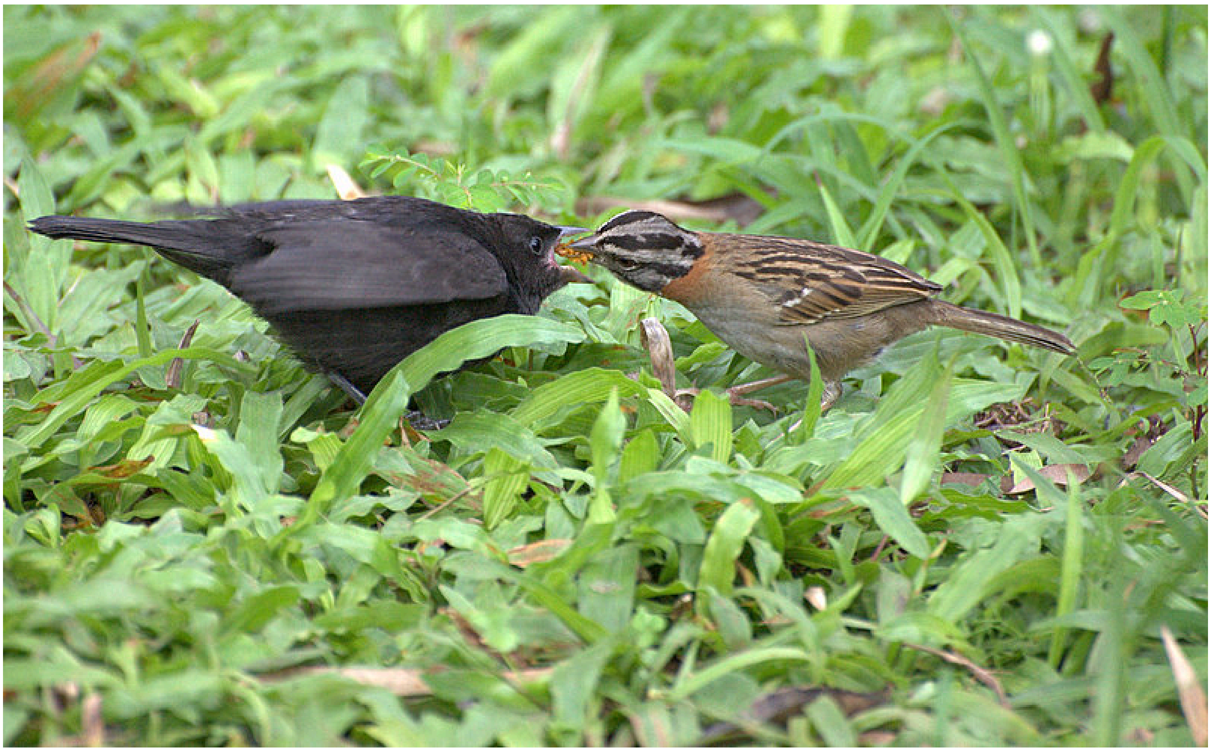
Aggressive mimicry need not involve the sense of vision. For example, the assassin bug preys on spiders, entering their web and plucking its silk threads. This produces vibrations that match the pattern of vibrations made by typical prey caught in the web, causing the spider to approach.

Bipolar mimicry systems

Mimicry systems involving only two species are known as bipolar. Only one bipolar arrangement is possible here, namely where the dupe is itself the model.

Brood parasitism

The brood parasite manipulates a host, either of the same or of another species, to raise its young as if it were its own, usually using egg mimicry, with eggs that resemble the host's. The strategy involves a form of aggressive mimicry called Kirbyan mimicry.
The evolutionary strategy relieves the parasitic parents from the investment of rearing young. This enables the parasitic parents to spend more time on other activities such as foraging and producing further offspring.



A shiny cowbird chick being fed by a rufous-collared sparrow

This benefit comes at the cost of provoking an evolutionary arms race between parasite and host as they coevolve: many hosts have developed strong defences against brood parasitism, such as recognizing and ejecting parasitic eggs, or abandoning parasitized nests and starting over. It is less obvious why most hosts do care for parasite nestlings, given that for example cuckoo chicks differ markedly from host chicks in size and appearance.

One explanation, the mafia hypothesis, proposes that parasitic adults retaliate by destroying host nests where rejection has occurred; there is experimental evidence to support this.
Intraspecific brood parasitism also occurs, as in many duck species. Here there is no visible difference between host and parasite eggs, which may be why the parasite eggs are so readily accepted. In eider ducks, the first and second eggs in a nest are especially subject to predation, perhaps explaining why they are often laid in another eider nest.

Similarity hypothesis

Common cuckoo females have been proposed to select hosts with similar egg characteristics to her own. The hypothesis suggests that the female monitors a population of potential hosts and chooses nests from within this group

Mafia hypothesis

The mafia hypothesis posits that brood parasite eggs are accepted by the host out of fear of retaliation (nest destruction) from the brood parasite, in an example of coevolution.

Amotz Zahavi proposed it in 1979, and it was tested by Manuel Soler in 1995.

Maria Abou Chakra, of the Max Planck Institute for Evolutionary Biology, with others, successfully mathematically modelled the mafia hypothesis as a viable strategy, conditional on two factors:

- hosts are capable of learning
- parasites revisit nests

Wicklerian-Eisnerian or mimicry of harmless species

The prey does not have to be attracted towards the predator for the predator to benefit: it is sufficient for the predator simply not to be identified as a threat. Wicklerian-Eisnerian mimics may resemble a mutualistic ally, or a species of little significance to the prey such as a commensal.

Mimicry of cleaner fish

Mimicry of mutualistic species is seen in coral reef fish, among the cleaning stations, where the models, certain cleaner fish, are greatly disadvantaged by the presence of the mimic.
The false cleanerfish (Aspidontus taeniatus) is a species of combtooth blenny, a mimic that copies both the dance and appearance of Labroides dimidiatus (the bluestreak cleaner wrasse), a similarly coloured species. It likely mimics that species to avoid predation, as well as to occasionally bite the fins of its victims rather than consume parasites. Most veiled attacks occur on juvenile fish, as adults that have been attacked in the past may avoid or even attack A. taeniatus.

Though A. taeniatus mimics L. dimidiatus in color, morphology, and mode of swimming, the false cleanerfish cheats much less often than initially reported. The primary reason for the false cleanerfish's mimicry is suggested to be not to cheat and feed on the flesh of client fish, but to avoid predation by those fish that do not prey on L. dimidiatus. Aggressive mimicry typically results in the complete consumption of prey by a mimic predator (such as anglerfish), or partial consumption of prey by an unattractive mimic. In both cases, the host fish can rarely or never learn the disguise of the mimic; the fact that A. taeniatus can be easily identified by client fish helps to dispel the notion that it is primarily an aggressive mimic.

One major difference in appearance between the false cleanerfish and its model is the location of the mouth.

Cryptic aggressive mimicry

Cryptic aggressive mimicry is where the predator mimics something that its prey is indifferent to. Unlike in all cases above, the predator is ignored by the prey, allowing it to avoid detection until the prey is close enough for the predator to strike. This is effectively a form of camouflage. The zone-tailed hawk (Buteo albonotatus), which resembles the turkey vulture (Cathartes aura), may provide one such example. It flies amongst them, suddenly breaking from the formation and ambushing its prey. There is some controversy over whether this is a true case of mimicry.

Parasites mimicking host prey

Just as predators such as anglerfish have a structure that lures their prey close enough for the anglerfish to devour them whole, so some parasites mimic their host's prey, but with roles reversed; the parasite gets eaten by the host. This deception provides the parasite easy entry into the host, which it can then feed upon, allowing it to continue its life cycle. Researchers may be able to predict the host of such parasites based on their appearance and behaviour. One such case is a genus of mussel, Lampsilis, which feeds on the gills of fish in the larval stage of their development. Once they mature, they leave the fish as adult mollusks. Gaining entry into the host is not an easy task, though, despite the fact that several hundred thousand larvae are released at once. This is especially true in flowing water bodies such as streams, where they cannot lie on the substrate and wait to be taken up in the course of foraging. Female Lampsilis have evolved a special technique for delivering their offspring into a suitable host. Structures on the edge of their mantle are able to capture the interest of fish. Some of these structures resemble small fish themselves, with eye spots, a "tail," and horizontal stripes, and may even move in a similar fashion, as if facing the current (rheotaxis). When overshadowed by a fish, the larvae are forcefully expelled, becoming ecto-parasites on their unsuspecting host. Some species of Lampsilis, notably Lampsilis ovata, attract fish in the genus Micropterus, while the genus Villosa has fish-like mantle lures that attract predatory fish such as Percina. Cercaria mirabilis, a trematode, has an especially large larval stage, a cercaria, which looks much like a small crustacean or mosquito larva. It mimics the locomotory behaviour of such animals, allowing it to be eaten by predaceous fish.

Another parasitic trematode example is seen in a terrestrial setting. Leucochloridium is a genus of flatworm (phylum Platyhelminthes) which matures in the intestine of songbirds. Their eggs pass out of the bird in the faeces and are then taken in by Succinea, a terrestrial snail that lives in moist environments. The eggs develop into larvae inside this intermediate host, and then must find their way into the digestive system of a suitable bird. The problem here is that these birds do not eat snails, so the sporocyst must find some way to manipulate its future host into eating it. Unlike related species, these parasites are brightly coloured and able to move in a pulsatile manner. A sporocyst sac forces its way into the snail's eye stalks and pulsates at high speed, enlarging the tentacle in the process. It affects the host's behaviour, causing the snail to move towards light, which it usually avoids. These combined factors make the sporocysts highly conspicuous, leading to their consumption by a hungry songbird. The snail then regenerates its tentacles, and Leucochloridium continues its life cycle.

Kleptoparasitism (meaning "parasitism by theft") is a form of feeding in which one animal deliberately takes food from another.

Western gull in pursuit of an elegant tern

Several species of gull steal food from humans, for example takeaway food at seaside resorts.

Some true flies (Diptera) are kleptoparasites. Within the family Milichiidae, commonly known as freeloader flies or jackal flies, adult milichiids visit spider webs to scavenge on half-eaten stink bugs. Flies in the genus Bengalia steal food and pupae transported by ants and are often found beside their foraging trails.

The relationship between spotted hyenas and lions, in which each species steals the other's kills, exemplifies kleptoparasitism. Cheetahs are common targets. Bears, coyotes and wolves are very opportunistic and all have this behaviour. Crab-eating macaques have also shown such tendencies. All hyena species engage in this behaviour when they can, as do jackals.

Golden Jackal

Human hunters may commonly take the remains of fresh kills from other carnivores, such as lions..

Such a strategy should only be followed if it is evolutionarily stable, meaning that it offers a selective advantage to individuals that practise it. Kleptoparasitism costs time and energy which could otherwise be spent directly on feeding, so this cost must be outweighed by the benefit in energy gained from the stolen food. Mathematical modelling suggests that when food is abundant, ordinary feeding is the best strategy; when food abundance falls below a critical level, kleptoparasitism suddenly becomes advantageous, and aggressive interactions become common. Similarly, when potential victims are rare or widely dispersed, the time needed to find them may not be justified by the food that might be stolen.

Evolutionary models of food sharing

Evolutionary biologists have developed various theoretical models to explain the evolution of food-sharing behaviour—"[d]efined as the unresisted transfer of food" from one food-motivated individual to another—among humans and other animals.

Models of food-sharing are grounded in general evolutionary theory and, when applied to human behaviour, fall within the realm of human behavioural ecology. Researchers have developed several types of food-sharing models, involving phenomena such as kin selection, reciprocal altruism, cooperation and tolerated theft.

Kin selection is a process whereby natural selection favours a trait due to its positive effects on the reproductive success of an organism's relatives, even when at a cost to the organism's own survival and reproduction. Kin selection can lead to the evolution of altruistic behaviour.

In biology, altruism refers to behaviour by an individual that increases the fitness of another individual while decreasing their own.

Reciprocal models of food-sharing generate expectations of when and how a recipient of food from a donor will share food in a future interaction with that donor.

Cooperation takes place when a group of organisms works or acts together for a collective benefit to the group as opposed to working in competition for selfish individual benefit.

Tolerated theft

Models of tolerated theft seek to explain why in some hunter-gatherer societies, scrounging behaviour is tolerated by other members of a group. According to variance reduction theory, it is more optimal to do so than to let excess food rot or spoil.

Mimicry of rewards

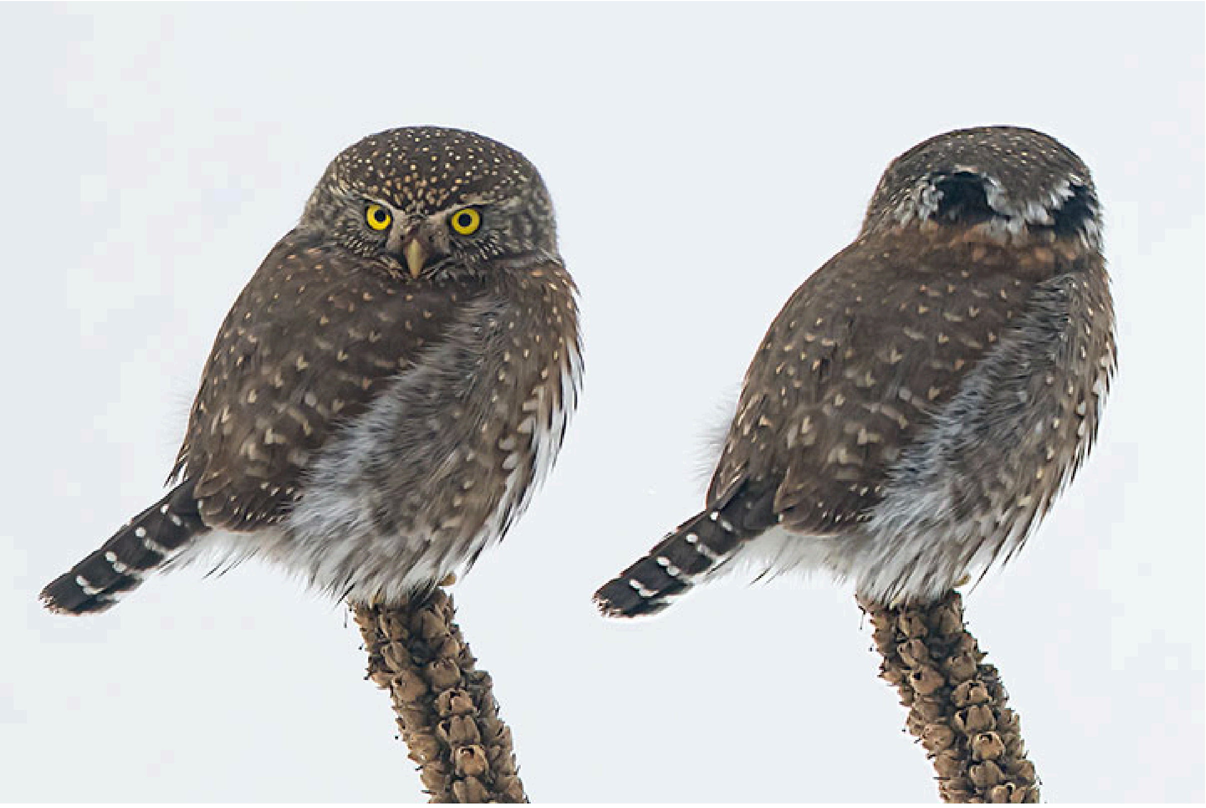
Flowering plants, sometimes in conjunction with fungi, mimic rewards which attract insects. Some "deceptive plants" imitate a pollinator's food source, with flower structures that resemble fruits.

In a complex case, floral mimicry is induced by the discomycete fungus Monilinia vaccinii-corymbosi. This fungal plant pathogen infects leaves of blueberries, causing them to secrete sugars, in effect mimicking the nectar of flowers. To the naked eye the leaves do not look like flowers, yet they still attract pollinating insects like bees using an ultraviolet signal. This case is unusual, in that the fungus benefits from the deception but it is the leaves that act as mimics, being harmed in the process. It is similar to host-parasite mimicry, but the host does not receive the signal. It has something in common with automimicry, but the plant does not benefit from the mimicry; instead, the pathogen's action is required to produce it.

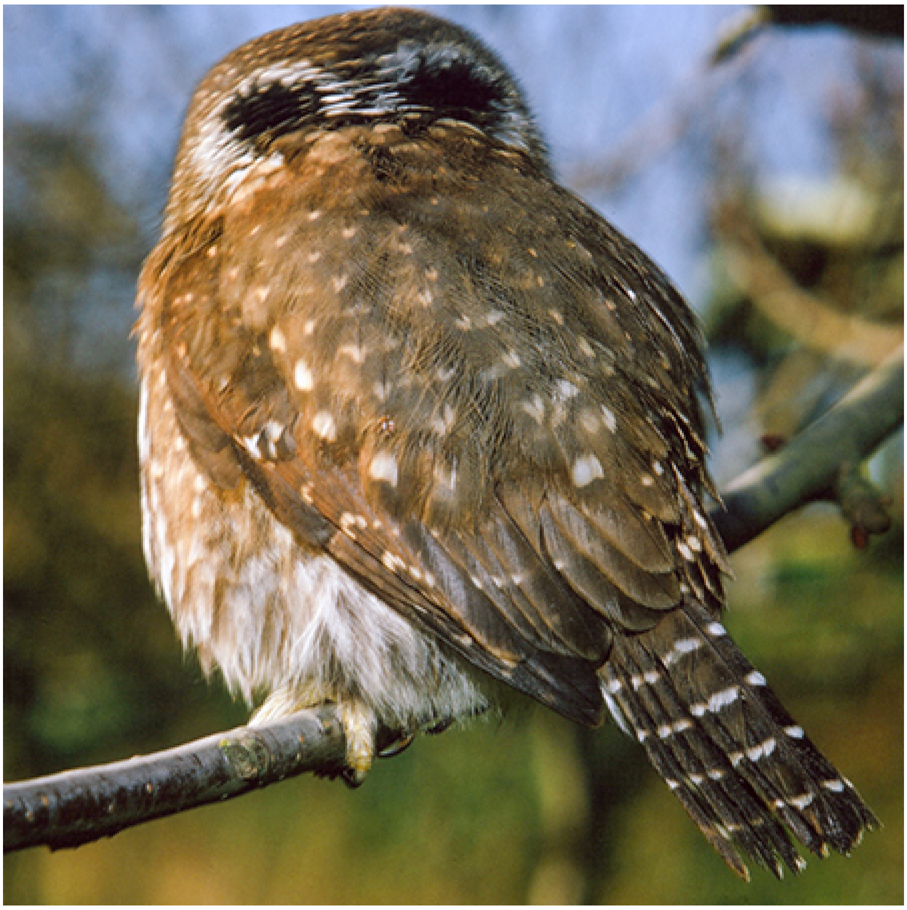
Pseudocopulation

Pseudocopulation describes behaviours similar to copulation that serve a reproductive function for one or both participants but do not involve actual sexual union. It is most generally applied to pollinators attempting to copulate with flowers. Some flowers mimic a potential female mate visually, but the key stimuli are often chemical and tactile. This form of mimicry in plants is called Pouyannian mimicry.

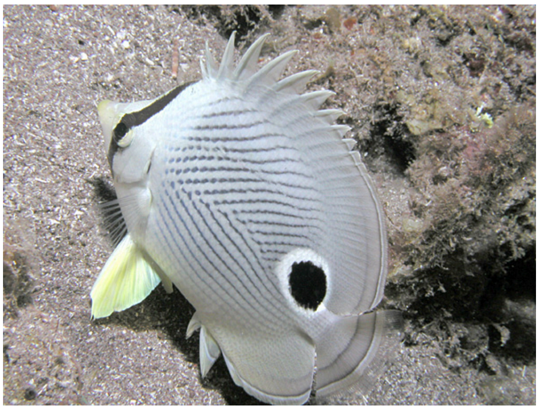
Automimicry



Automimicry refers to instances in which one body part of an animal mimics another. This may help an animal survive an attack, or help predators to appear innocuous.

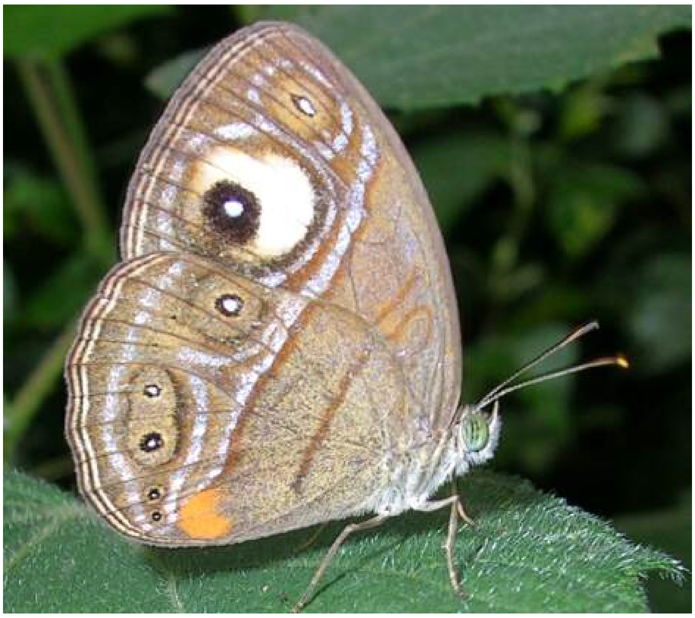


Several species of pygmy owl bear false eyes on the back of the head, misleading predators into reacting as though they were the subject of an aggressive stare.



Foureye butterflyfish mimic its own eyes which are camouflaged with a disruptive eye mask.

Eyespot

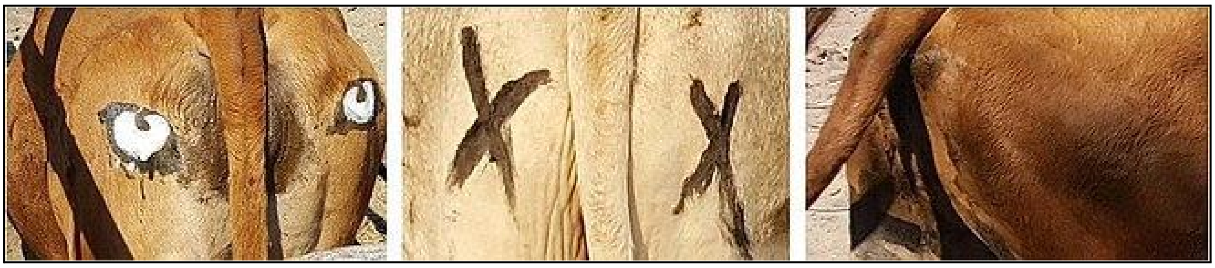


An eyespot (sometimes ocellus) is an eye-like marking.

Many butterflies, such as this gladeye bushbrown (Mycalesis patnia), have eyespots on their wings.

Eyespots could be explained in at least three different ways. They may be a form of mimicry in which a spot on the body of an animal resembles an eye of a different animal, to deceive potential predator or prey species. They may be a form of self-mimicry, to draw a predator's attention away from the prey's most vulnerable body parts. Or they may serve to make the prey appear inedible or dangerous. Eyespot markings may play a role in intraspecies communication or courtship; the best-known example is probably the eyespots on a peacock's display feathers.
The pattern-forming biological process (morphogenesis) of eyespots in a wide variety of animals is controlled by a small number of genes active in embryonic development, including the genes called Engrailed, Distal-less, Hedgehog, Antennapedia, and the Notch signalling pathway.

Artificial eyespots have been shown to reduce predation of cattle by lions.



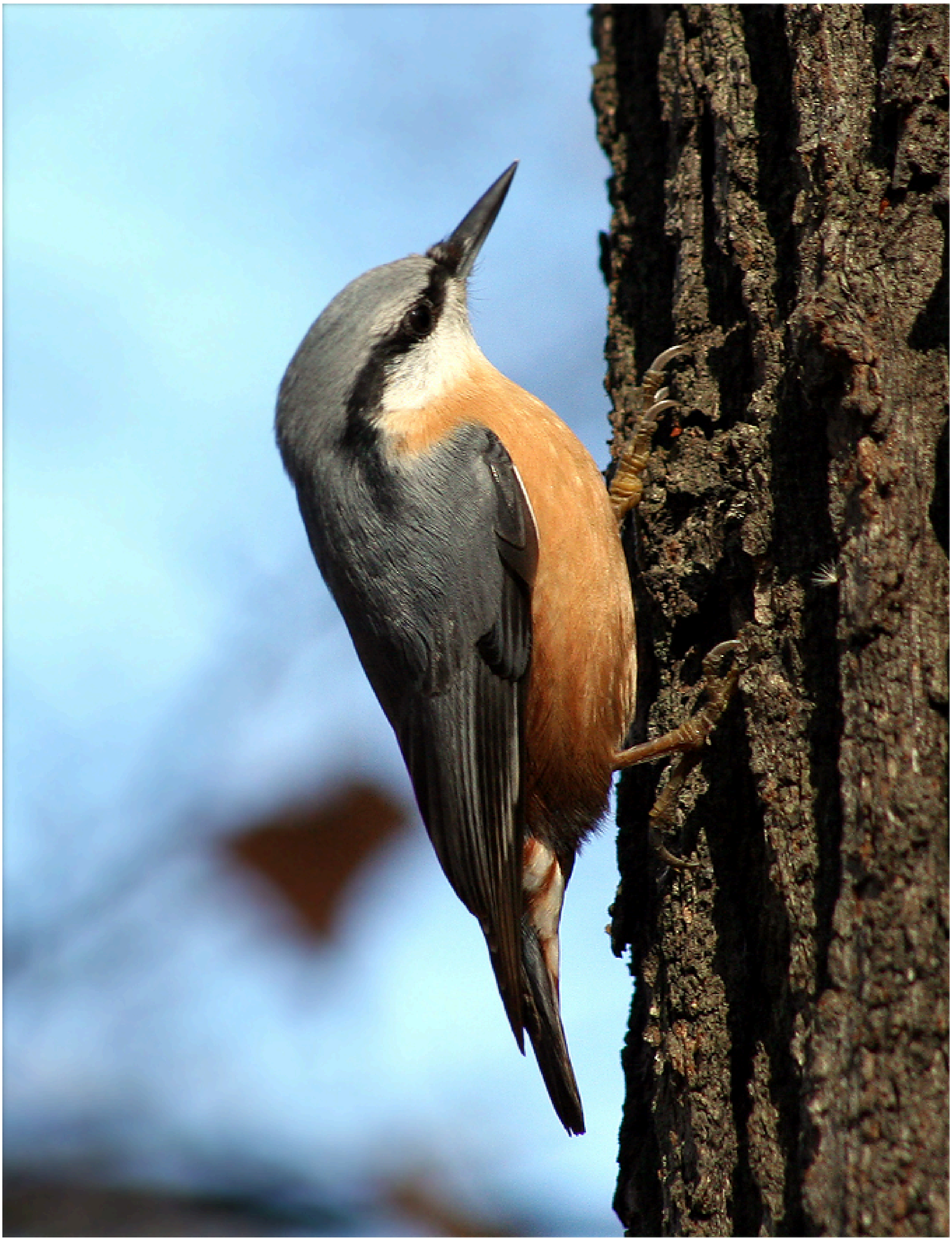
Eyespot experiment on cattle in Botswana. Both the eyespots (left) and the cross markings (centre) protected the cattle from predation by lions, compared to the unmarked controls (right).

The cattle were always in mixed groups of marked and unmarked animals; it is not known whether marking all animals in a herd would provide effective protection.

Disruptive eye masks

The eye has a distinctive shape and dark coloration dictated by its function, and it is housed in the vulnerable head, making it a natural target for predators. It can be camouflaged by a suitable disruptive pattern arranged to run up to or through the eye, sometimes forming a camouflage eyestripe.

The zoologist Hugh Cott recognized the importance of concealing the eye in his 1940 book Adaptive Coloration in Animals. He highlights the 'inherent conspicuousness of an eye-spot,' which 'stands out from everything else and rivets the attention.' In his words: 'The disruptive value of a pattern lies in its tendency to hide the real form of an animal by suggesting a false form [...] So long as the false configuration is recognized in preference to the real one, concealment will be effected.'



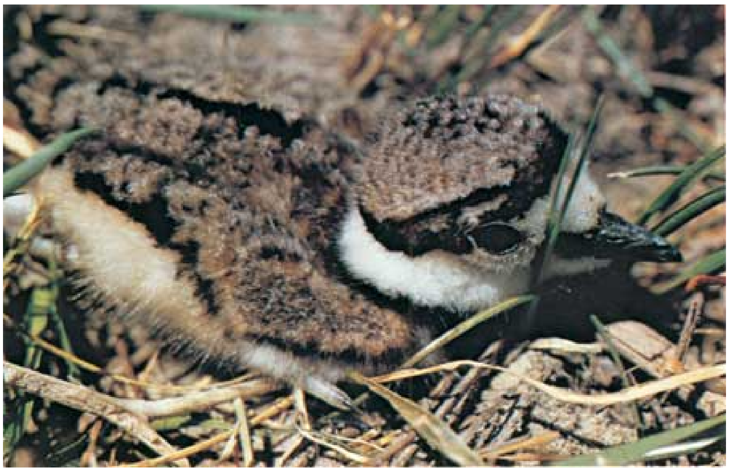
The Eurasian nuthatch has a stripe joining the beak, eye, and body

Disruptive coloration

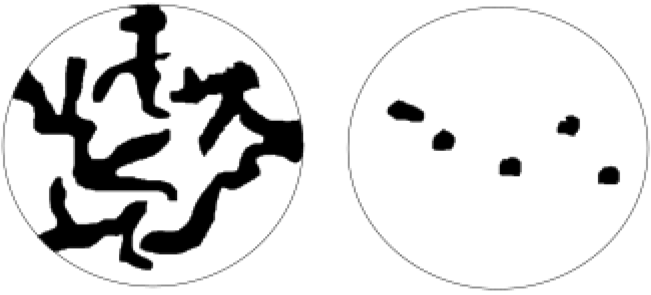
Disruptive coloration works by breaking up the outlines of an animal, with a strongly contrasting pattern. It is often combined with other methods of crypsis including background colour matching and countershading.

“The function of a disruptive pattern is to prevent, or to delay as long as possible, the first recognition of an object by sight” noted Hugh Cott.

Further, he explains that under ideal conditions, background colour matching together with countershading would "suffice to render an animal absolutely invisible against a plain background".



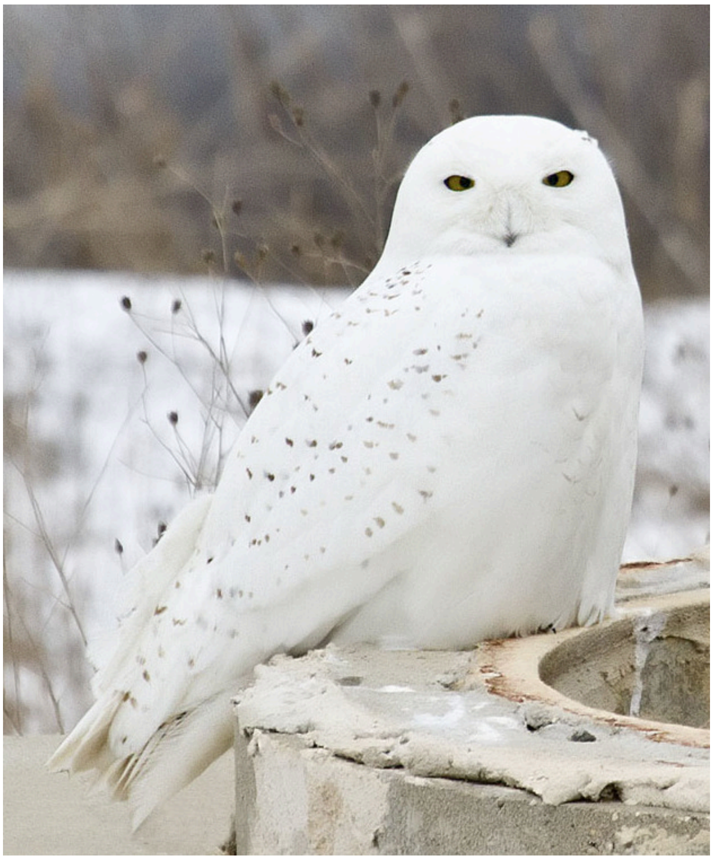
The bold disruptive pattern of the killdeer chick's plumage helps this precocial bird avoid detection in its open-prairie environment.



Disruptive and distractive both rely on conspicuous markings, but differ in their mechanisms and so in the size and position of the markings for greatest effectiveness.

Distractive markings

Distractive markings draw the observer's attention away from the object as a whole.



Snowy owl

Camouflage

Camouflage is a method of concealment that uses materials, colours, or light to blend animals or objects into their surroundings.

While camouflage can increase an organism's fitness, it has genetic and energetic costs. There is a trade-off between detectability and mobility. Species camouflaged to fit a specific microhabitat are less likely to be detected when in that microhabitat, but must spend energy to reach, and sometimes to remain in, such areas. Outside the microhabitat, the organism has a higher chance of detection.

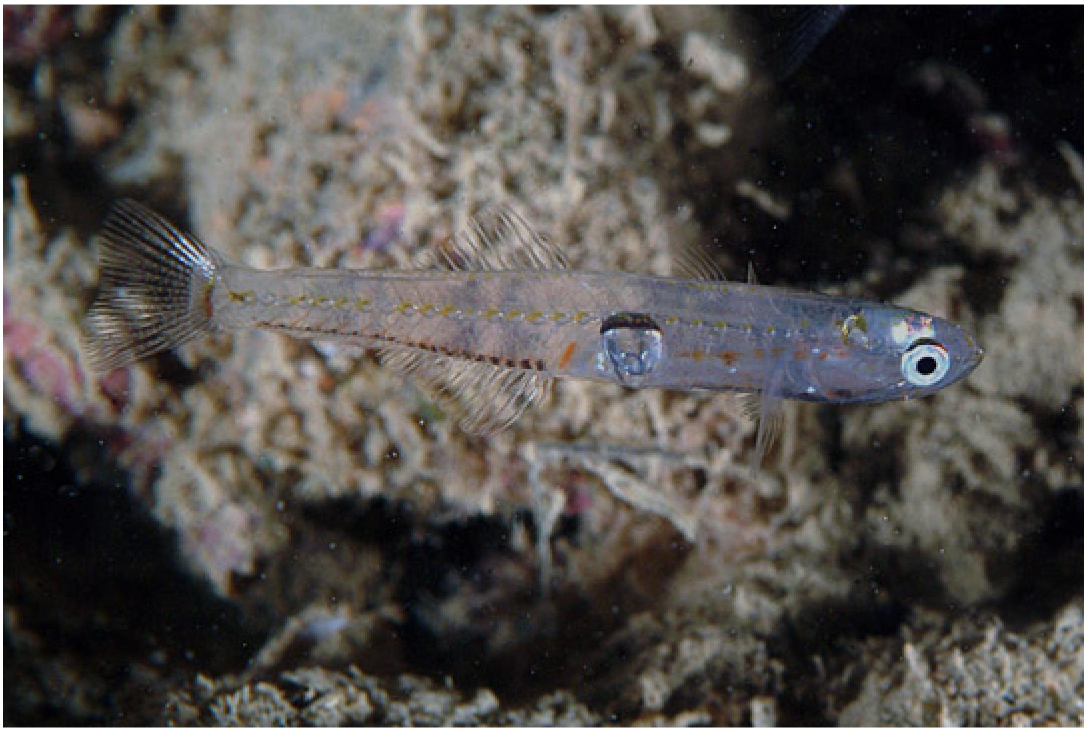
Generalised camouflage allows species to avoid predation over a wide range of habitat backgrounds, but is less effective.

The development of generalised or specialised camouflage strategies is highly dependent on the biotic and abiotic composition of the surrounding environment.

In the open ocean, where there is no background, the principal methods of camouflage are transparency, silvering, and countershading.

Transparency

Transparency is common, even dominant, in animals of the open sea, especially those that live in relatively shallow waters. It is found in plankton of many species, as well as larger animals such as jellyfish.



The transparent goby

Some tissues such as muscles can be made transparent if they are either very thin or organised as regular layers or fibrils that are smaller than the wavelength of visible light. Familiar examples of transparent body parts are the lens and cornea of the vertebrate eye. The lens is made of the protein crystallin; the cornea is made of the protein collagen. Other structures cannot be made transparent, notably the retinas or equivalent light-absorbing structures of eyes—they must absorb light to be able to function.

Silvering

Where transparency cannot be achieved, it can be imitated effectively by silvering to make an animal's body highly reflective. At medium depths at sea, light comes from above, so a mirror oriented vertically makes animals such as fish invisible from the side.

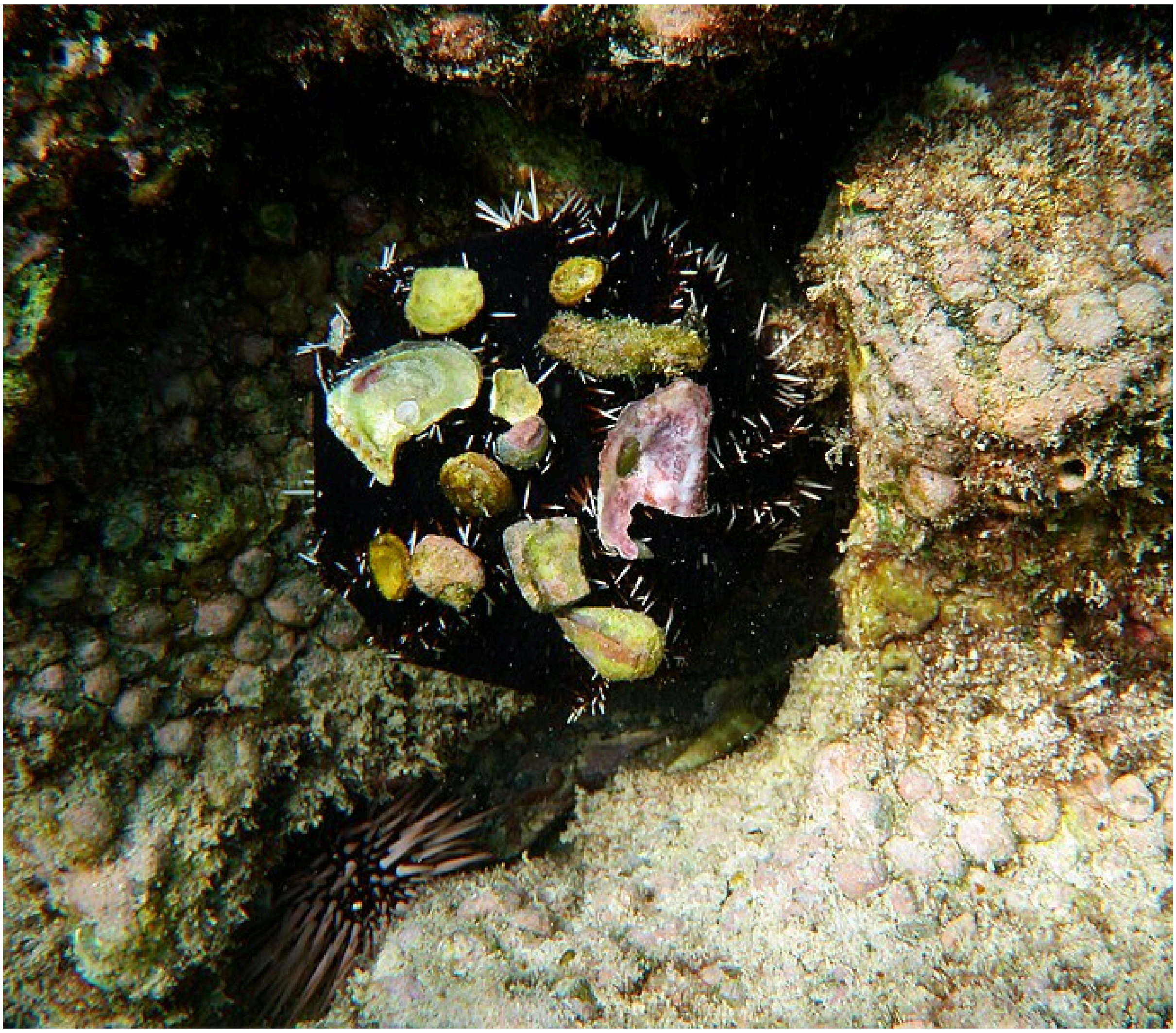
Atlantic herring is a typical silvered fish of medium depths.

Self-decoration

Self-decoration is a method of camouflage in which animals select and attach materials—sometimes living—from their environment to themselves for concealment.

The method was described in 1889 by William Bateson, who observed Stenorhynchus decorator crabs.

In *The Colours of Animals* (1890) by Edward Bagnall Poulton, it was classified as "adventitious protection," and as "adventitious concealing coloration" or "adventitious resemblance" in Hugh Bamford Cott's textbook *Adaptive Coloration in Animals* (1940), who compared it to the way Australian Aborigines stalked waterfowl by covering their faces with water lily leaves.



Sea Urchin decorated with shells

In 1889, William Bateson observed in detail the way that decorator crabs fix materials on their backs. He noted that "the whole proceeding is most human and purposeful", and that if a Stenorhynchus crab is cleaned, it will "immediately begin to clothe itself again with the same care and precision as before".

They decorate themselves by sticking mostly sedentary animals and plants to their bodies as camouflage, or if the attached organisms are noxious, ward off predators through aposematism.

Hugh Cott described the decorator crabs as using "concealment afforded by masks of adventitious material", giving as example the great spider crab Hyas araneus of Britain "which disguises itself very perfectly". When H. araneus specimens were moved from an environment where all the crabs were camouflaged with short pieces of seaweed into different environments, all of them had redecorated themselves with local materials after one night. One was among corallines, and was covered with a dense bush of the Sertularia abietina (a hydrozoan). Another was on small shells and gravel, and was decorated with those. A third was among the Antedon rosaceus (a crinoid), and had broken off pieces of crinoid arms as decoration.

Ultra-blackness

Extremely black surface, matching very dark background.

Moving on to the deep sea, some fishes have very black skin, reflecting under 0.5% of ambient light. Oneirodes had a particularly black skin which reflected only 0.044% of 480 nm wavelength light. The ultra-blackness is achieved with a thin but continuous layer of particles in the dermis, melanosomes. These particles both absorb most of the light, and are sized and shaped so as to scatter rather than reflect most of the rest. Modelling suggests that this camouflage should reduce the distance at which such a fish can be seen by a factor of 6 compared to a fish with a nominal 2% reflectance. Species with this adaptation are widely dispersed in various orders of the phylogenetic tree of bony fishes (Actinopterygii), implying that natural selection has driven the convergent evolution of ultra-blackness camouflage independently many times.

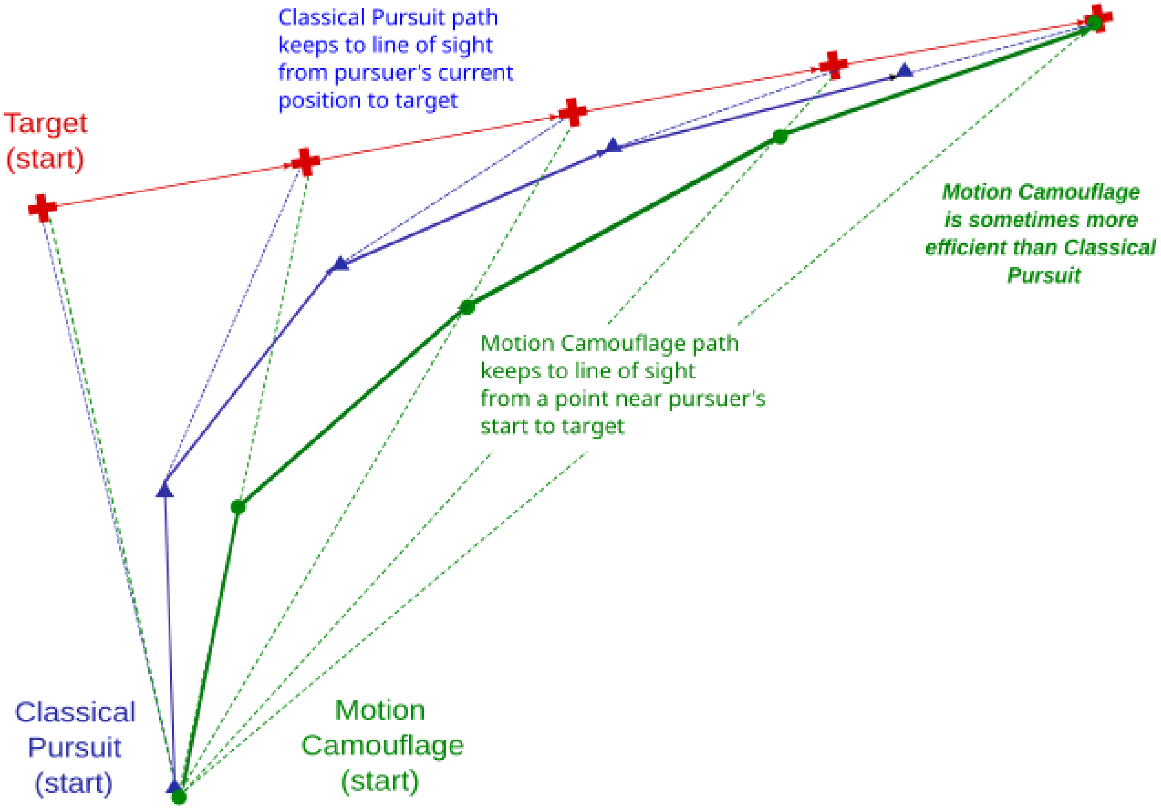
Active camouflage

Some animals, such as chameleons and octopuses, are capable of actively changing their skin pattern and colours.

In his Origin of Species, Darwin wrote:

When we see leaf-eating insects green, and bark-feeders mottled-grey; the alpine ptarmigan white in winter, the red-grouse the colour of heather, and the black-grouse that of peaty earth, we must believe that these tints are of service to these birds and insects in preserving them from danger. Grouse, if not destroyed at some period of their lives, would increase in countless numbers; they are known to suffer largely from birds of prey; and hawks are guided by eyesight to their prey, so much so, that on parts of the Continent persons are warned not to keep white pigeons, as being the most liable to destruction. Hence I can see no reason to doubt that natural selection might be most effective in giving the proper colour to each kind of grouse, and in keeping that colour, when once acquired, true and constant.

Motion camouflage



The attacker chooses its path so as to remain on the line between the target and a landmark. This allows the attacker to approach while appearing stationary from the target's viewpoint. The attacker looms larger as they close in on the target, but does not otherwise appear to move.

Mimicking optic flow of background

Australian emperor dragonfly

This is the main focus of work on motion camouflage, and is often treated as synonymous with it.

Stealthy movements

One strategy is to minimise actual motion, as when predators such as tigers stalk prey by moving very slowly and stealthily.

Minimising motion signal

When movement is required, one strategy is to minimise the motion signal, for example by avoiding waving limbs about.

Camouflage is sometimes facilitated by motion.

As with the leafy sea dragon and some stick insects, which complement their passive camouflage by swaying like plants in the wind or ocean currents, delaying their recognition by motion crypsis.

Motion crypsis and motion masquerade

Movement catches the eye of prey animals on the lookout for predators, and of predators hunting for prey. Most methods of crypsis therefore also require suitable cryptic behaviour, such as lying down and keeping still to avoid being detected, or in the case of stalking predators such as the tiger, moving with extreme stealth, both slowly and quietly, watching its prey for any sign they are aware of its presence. As an example of the combination of behaviours and other methods of crypsis involved, young giraffes seek cover, lie down, and keep still, often for hours until their mothers return; their skin pattern blends with the pattern of the vegetation, while the chosen cover and lying position together hide the animals' shadows. The flat-tail horned lizard similarly relies on a combination of methods: it is adapted to lie flat in the open desert, relying on stillness, its cryptic coloration, and concealment of its shadow to avoid being noticed by predators. In the ocean, the leafy sea dragon sways mimetically, like the seaweeds amongst which it rests, as if rippled by wind or water currents. Swaying is seen also in some insects, like Macleay's spectre stick insect, Extatosoma tiaratum. The behaviour may be motion crypsis, preventing detection, or motion masquerade, promoting misclassification, or a combination of the two.

Motion dazzle

Most of the methods help to hide against a background; but motion dazzle protects without hiding.

Motion dazzle confuses the observer with a conspicuous pattern, making the object visible but momentarily harder to locate.

It may degrade predators' ability to estimate the prey's speed and direction accurately, giving the prey an improved chance of escape. Motion dazzle distorts speed perception and is most effective at high speeds; stripes can also distort perception of size (and so, perceived range to the target).

Predator confusion

As the group moves, the predator has greater difficulty targeting an individual prey animal.

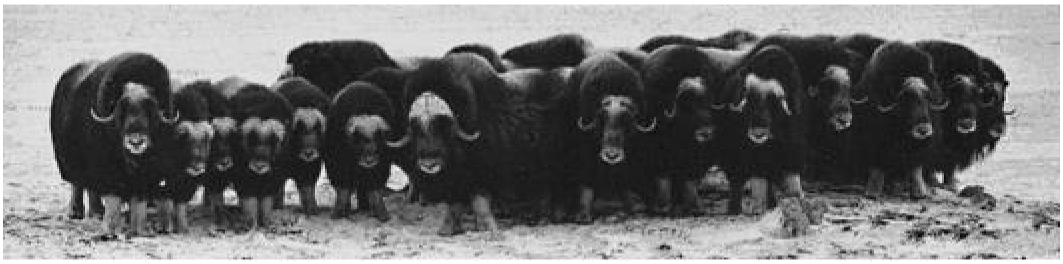
A single zebra is hard to catch amongst a herd.

Furthermore, when moving rapidly, the zebra stripes create a confusing, flickering motion dazzle effect in the eye of the predator.

This theory is based on the idea that it becomes difficult for predators to choose individual prey from groups because the many moving targets create a sensory overload of the predator's visual channel.

Mobbing

Mobbing is the harassing of a predator by many prey animals.



Group of muskoxen in defensive formation, horns ready.

Historical views

The broadcaster David Attenborough stated: "People who accuse us of putting in too much violence, [should see] what we leave on the cutting-room floor." It is contended that wildlife documentaries present nature as a spectacle to be passively consumed by viewers, as well as a sacred and unique place that needs protection. Additionally, attention is drawn to how hardships that are experienced by animals are portrayed in a way that gives the impression that wild animals, through adaptive processes, are able to overcome these sources of harm. The development of such adaptive traits takes place over a number of generations of individuals who will likely experience much suffering and hardship in their lives, while passing down their genes.

David Pearce, a transhumanist and advocate for technological solutions to reduce wild animal suffering, is highly critical of wildlife documentaries' portrayal of this suffering. He argues: “Wildlife shows have their sad moments, for sure. Yet suffering never lasts very long. It is always offset by homely platitudes about the balance of Nature, the good of the herd, and a sort of poor-man's secular theodicy on behalf of Mother Nature, which reassures us that it’s not so bad after all.”

Predation has historically been viewed as a natural evil within the context of the problem of evil and has been considered a moral concern for Christians who have engaged with theodicy. Natural evils have been sometimes thought of as something that humans should work towards alleviating, or as part of a greater good which justifies the existence of this type of evil. Thomas Aquinas advocated the latter view, arguing that "defects" in nature such as predation led to the "good of another, or even to the universal good" and that if "all evil were prevented, much good would be absent from the universe"

Within Christian and Hebrew Scripture, there are several prophecies which describe a future Heaven or Earth where predation is no longer a feature of nature,[13] including Isaiah's prophecy that "[t]he wolf shall live with the lamb, the leopard shall lie down with the kid, the calf and the lion and the fatling together, and a little child shall lead them."

In his notebooks (written between 1487 and 1505), Leonardo da Vinci questioned why nature was not structured in a way which meant that animals were not forced to consume each other to survive.

David Hume made several observations about predation and suffering experienced by wild animals in Dialogues Concerning Natural Religion (1779), stating that the "stronger prey upon the weaker, and keep them in perpetual terror and anxiety".

The inevitability of such cycles of destruction and creation was a cause for Leopardi's philosophical pessimism. In Zibaldone, published posthumously in 1898, Leopardi argued that predation is the ultimate indication of the evil design of nature.

The American zoologist and animal rights philosopher J. Howard Moore, in The New Ethics (1907), labelled carnivorous species as "criminal" races whose "existence is a continual menace to the peace and well-being of the world" because the "fullness of their lives is dependent upon the emptiness and destruction of others". In the pamphlet Why I Am a Vegetarian, published in 1895, Moore described the Carnivora as "relentless brutes", whose existence is a travesty for ethics, justice and mercy. In Better-World Philosophy (1899), Moore argued that carnivorousness was the result of excessive egoism, a product of natural selection, stating "Life riots on life".

The English philosopher Stephen R. L. Clark's "The Rights of Wild Things" (1979) is considered to be one of the first ethics papers to explicitly engage with predation as a problem. In the paper, Clark argues that the concept that humans are obligated to aid animals against predators is not absurd, but that it follows only in the abstract, not in practice.

Some ethicists have made concrete proposals for reducing or preventing predation, including stopping the reintroduction of predators in locations where they have previously gone extinct.

In the context of ecology, predation is considered to play a crucial and necessary role in the ecosystem. This has led some writers to reject predation as being a moral issue at all.

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Anti-predator adaptation
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